CAN AGROFORESTRY IMPROVE SOIL WATER AND TEMPERATURE DYNAMICS IN AGRICULTURE? A CASE STUDY WITH SYNTROPIC FARMING IN BAHIA, BRAZIL

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Abstract

We investigated the potential of Syntropic agriculture (SA) to improve rural soil water and temperature resilience in Northeastern Brazil. Water content in SA was found to be 13% higher on average than in cocoa monoculture (MO) and, after several days without rain, also higher than in a regrowth forest (RF). Mean soil temperature was lowest in RF, intermediate in SA and highest in MO, where it was also more affected by the hour of the day and by precipitation. Factors likely responsible for these differences include canopy density and stratification, litter type and thickness, soil organic matter and compaction. SA thus markedly improves soil water and temperature dynamics over MO, and can be at least as performant as natural succession at restoring a healthy water cycle on degraded soils. Indications suggest that SA would be capable of similar improvements in Europe, opening the door for further research.

Keywords: climate change; soil water; soil temperature; water retention capacity; temporal variability; agroforestry; ecosystem restoration

Introduction

Conventional agriculture practices have made soil processes increasingly vulnerable to extreme weather events, which are predicted to intensify worldwide in the face of climate change (e.g., Madsen et al. 2014; Min et al. 2011). In this context, we investigated the potential of Syntropic agriculture, a successional and process based form of agroforestry, to improve soil water and temperature resilience in agricultural production.

Materials and methods

The Syntropic agriculture (SA) system was developed by Swiss farmer and researcher Ernst Götsch in the humid tropics of Bahia, Brazil. The aim of the current study was to gain insight into how these techniques influence soil water and temperature dynamics over time and as a reaction to wet and dry periods. Therefore, we compared Ernst’s farm with a neighboring cocoa monoculture (MO) and unmanaged regrowth Atlantic rainforest (RF). The latter two systems were chosen as controls since they are the most common land uses in the region for, respectively, economically viable agricultural production and for nature preservation, i.e. the two functions which SA aims to combine (de Souza 2015; Passini 2017; Peneireiro 1999).

For each of the three systems, one study site was selected in such a way that all sites were in close proximity of each other and had similar characteristics of hillside position, slope, orientation, soil type, soil texture and site history. The dynamics were monitored daily on each site during a 30 day period in November – December 2017. Measurements were taken via electromagnetic induction with the WET-2 sensor from Delta-T instruments and carried out in the upper 7cm of topsoil, i.e. the soil horizon expected to show the most variation within the timeframe of the experiment. To ensure statistical significance, 3 plots were demarcated per site, each with 4 fix measurement points and 5 replicates per point. Rainfall data was collected using a pluviometer. Finally, soil moisture and temperature data were analyzed using linear mixed models, as well as Student's t-tests for pairwise comparison of sites.

Results

During the experiment, 3 rainy periods were observed, each separated by 4 to 7 dry days. Water content in SA was found to be on average 13% higher than in MO, being significantly higher on all days except the first days of rain events. From the second day of rain events onward, water content in SA would consistently and significantly surpass MO. Despite this fact, surface runoff was observed only in MO, indicating a lower water retention capacity in the latter. When rains stopped and a dry period progressed, levels in SA would remain superior to MO. Soil moisture in the RF site evolved similarly to SA during rain events. However, after 2 to 5 dry days, levels became significantly lower, i.e. closer to MO (Figure 1a).

Soil temperature was on average lowest in RF, intermediate in SA and highest in MO, each separated by 0.6-1°C. In the latter system it was also significantly more variable, depending on the hour of the day and on wet and dry spells (Figure 1b).

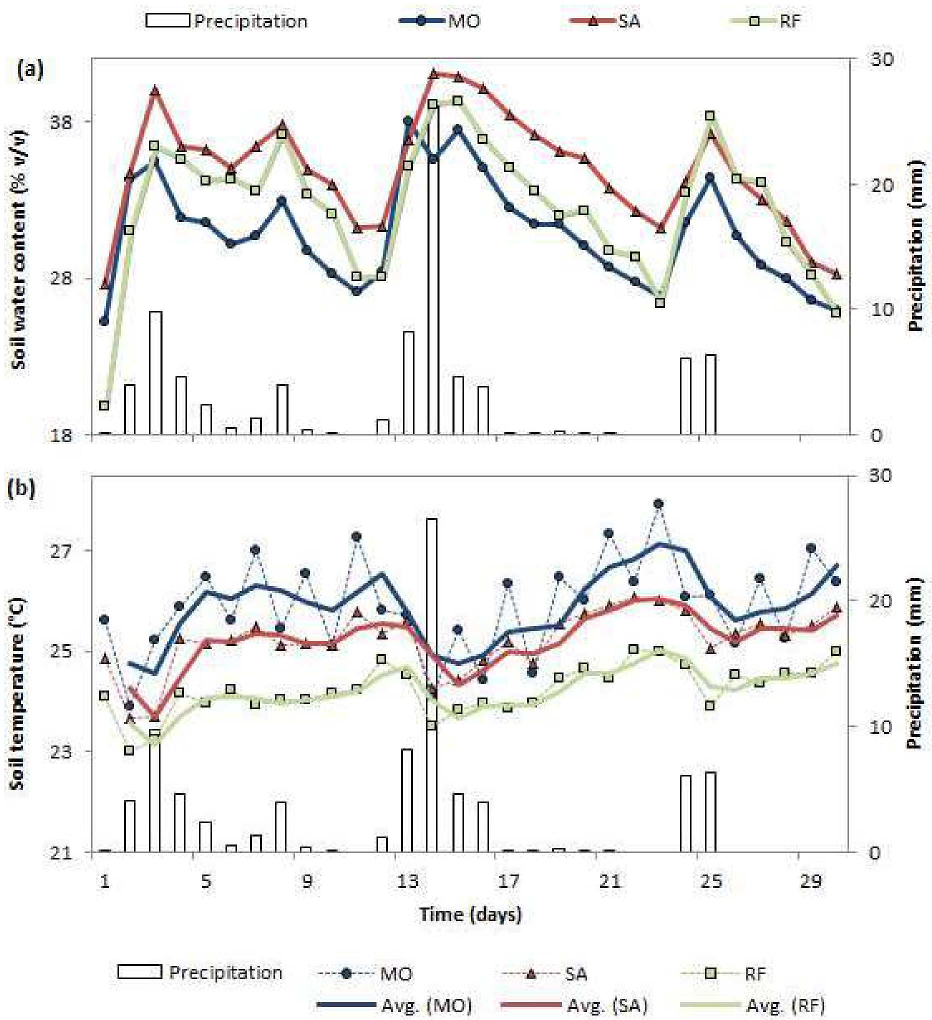

Figure 1: Evolution through time for the 3 studied systems of (a) average water content and (b) average soil temperature. In (b) both daily means (dotted lines) and two-day averages (continuous lines) are included. Note: A dry period of 14 days had preceded the first day of measurements.

Discussion

Among the factors affecting our results, the lower organic matter content and more compacted soil structure in MO likely explain its reduced capacity to absorb rain water and prevent runoff compared to the other sites (Charman and Murphy 1998).

However, of even greater influence is soil cover by litter and canopy. Firstly, this cover slows the wetting of soil by buffering the effect of rain (Greene and Hairsine 2004; Gyssels et al. 2005). This explains why, on the first day of rain events, soil moisture levels rose more slowly in SA whereas the exposed soil in MO wetted faster. Secondly, it also slows the drying of soil by insulating from solar radiation, evaporation and wind (e.g., Baptista et al. 2014; Villegas et al. 2010). This in turn likely explains the higher moisture content in SA compared to MO overall, and to RF in the case of prolonged dry periods. The latter finding may seem remarkable and counterintuitive, and additional studies would be required to confirm this effect conclusively. Nevertheless, it is possible that soil cover is indeed more insulating in SA even than in an unmanaged forest due to the specific management. Namely, the intense pruning in SA creates a biomass flux to the litter layer 25% to 150% higher than values for unmanaged secondary Atlantic forests found in literature (Schulz et al. 1994; Martinelli et al. 2017). Moreover, it provides a higher fraction of woody material such as branches and logs, which could further enhance water absorption and retention. According to Ernst Götsch, the canopy stratification pattern maintained between species in his system also contributes to conveying more moisture towards the ground than in an unmanaged forest. A final relevant effect of litter and canopy cover is to lower soil temperature (e.g., Tan and Layne 1993).

On the basis of these effects, one would expect systems with higher water retention to also show lower temperatures, both driven by soil cover. This was mostly the case except for RF compared to SA in dry periods, when the latter system showed higher water content as well as higher temperatures. Possibly, a different *balance* between litter and canopy cover plays a role here. Indeed, pruning in SA may result in a particularly insulating litter layer and a moisture-conveying canopy stratification. Yet it also opens up this canopy which increases incident sunlight and therefore temperatures. While this would enhance evaporative potential in SA (Baptista et al. 2014), our results suggest that the effect of litter cover prevails.

In a tropical context, higher temperatures enhance soil nutrient release but in the long term also nutrient depletion and thus the need for external fertilization (BassiriRad 2005). It also increases the loss of soil carbon and nitrogen through volatilization (Kirschbaum 1995). These effects imply negative ecosystem consequences for MO, which had the highest and by far the most variable temperatures.

The European context

In Europe too, soil water and temperature management in agriculture is becoming an increasingly 'hot' topic. Extreme precipitation events are likely to intensify across Europe in the wake of climate change (Madsen et al. 2014), making the ability of landscapes to absorb rainwater ever more crucial to prevent flooding and soil loss. In turn, water retention during dry periods is especially relevant in the Mediterranean climate zone where, in addition to the already dry summers, occurrence of drought years is predicted to increase (Gudmundsson and Seneviratne 2016).

While the drivers behind our findings would also hold in a temperate climate, their relative importance may vary and change the overall picture to some extent. For instance, at lower temperatures primary production is reduced but organic matter breakdown is reduced even further, promoting net accumulation (Kirschbaum 1995). The additional litter input from pruning in Syntropic farming would thus not be as great as in a tropical situation, but it would persist longer. As a result it is probable that, in Europe, these techniques also provides a more protective cover to absorb and retain moisture compared to an unmanaged ecosystem. However, the extent remains to be researched and likely depends on site-specific climate, soils and species used.

Farms in both the Netherlands and around the Mediterranean which we contacted and which apply Syntropic agriculture or very similar techniques, have also reported various improvements of soil processes both over the time and compared to neighboring conventional farms. These included a more constant soil temperature and increased humidity.

Conclusion

Our results show that SA markedly improves soil water and temperature dynamics over a conventional monoculture. They also suggest that this system is at least as performant as unmanaged natural succession, if not more so, at restoring a healthy water cycle on degraded soils in the humid tropics. This establishes SA as a valuable ally in mitigating the effects of climate change. There are good indications that these findings would hold in a temperate European environment. Our work may thus serve as an invitation and guide for further research to investigate this question and consolidate the body of evidence. It is after all crucial for shaping policies and raising awareness of the public that hard data on this subject of global importance be gathered, whether or not it confirms what people working with these techniques may readily observe.

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